

POTASSIUM AVAILABILITY IN PARSONS SILT
LOAM AS INFLUENCED BY SOIL DRYING AND
ALTERATION OF THE CATION EXCHANGE CAPACITY

by

DONALD LEROY REED

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INTRODUCTION AND REVIEW OF LITERATURE

The importance of potassium for crop production has been recognized since the beginning of the nineteenth century. Often referred to as the third fertilizer element, its importance as a constituent of commercial fertilizer has not been realized until comparatively recent times. The mysterious behavior of potassium in the soil has been extensively investigated in only the past 25 or 30 years.

The effects of soil drying, cationic balances, and soil organic matter upon potassium availability and uptake have been noted. In this study, an attempt was made to determine the effect of increasing the cation exchange capacity of the growth medium upon potassium availability. It also was the purpose of this investigation to determine the effect of such increase in exchange capacity upon potassium availability as it exists in both continuously moistened and previously dried soil.

Volk (22) was one of the first workers to establish that a portion of potassium applied to soils as fertilizers is converted to a nonexchangeable form. The fixation was found to depend upon the nature and quantity of colloids present. Alternate wetting and drying of soil treated with soluble potassium salts was found to facilitate this fixation.

Hoagland and Martin (10) observed that soil high in replaceable potassium tended to induce "luxury" consumption of this element by crops grown on it. Under intensive cropping conditions, the proportion of potassium derived from the nonexchangeable form increases until that point is reached at which exchangeable potassium is no longer supplied. The solubility of the nonexchangeable form determines the supplying power of the soil at this point.

Fine, et al. (7) found that freezing, caused a greater release of potassium from a previously treated soil than from an untreated soil.

Attoe (3) determined that drying of unfertilized soils at room temperature increased the content of exchangeable potassium.

Scott and Smith (20) concluded that drying approximately doubled the exchangeable potassium content of Parsons silt loam. Furthermore, it appeared that a single unit of exchangeable potassium in continuously moistened soil was from 20 to 26 percent more available to plants than the same unit in dried soil.

According to Reitemeier (19) the various forms of soil potassium are interrelated. The availability to plants depends on the rate of release to the available forms from the reserve supplies.

The 13 soils employed in the greenhouse study by Luebs, et al. (14) showed variable increases in exchangeable potassium content upon air drying. However, results obtained in both field and laboratory showed that not much increase in exchangeable potassium occurred until the soil moisture level had dropped to near five percent or below.

Legg and Beachler (12) suggested that favorable response to potash fertilization may be expected on soils with exchange capacities above 5 m.e./100 grams and nitric acid-extractable potassium levels below 250 ppm K, providing other nutrients are adequate.

Williams and Jenny (24) reported the descending order of effectiveness of ions for replacement of K from the soil to be $H^+ > Na^+ > Li^+ > Ca^{++} > Mg^{++} > NH_4^+$. All except NH_4^+ replaced nonexchangeable potassium from soil.

However, Pratt, et al. (18) concluded that incubations of samples of the same soil with various cations in the exchange complex indicated higher potassium release from nonexchangeable forms with calcium rather than hydrogen

as the exchangeable cation.

Cation release studies by Bower and Wadleigh (5) as well as others (1) established that the order of the ease of replacement of various metallic cations adsorbed upon the cation-exchange resin (Amberlite 1R-100) was the same as that generally found for the soil colloids; namely, $\text{Na} > \text{K} > \text{Mg} > \text{Ca}$.

Amberlite cation-exchanger is a phenol-formal-dehyde resin in which the hydrogen of the phenolic group is exchangeable for other cations. An indirect conclusion that Amberlites might have been presumed not to be toxic for plant growth was drawn from the work of Liebig, et al. (13), who found cation and anion--Amberlites suitable for purification of water used in nutrient solutions.

Graham and Albrecht (9) found that nitrate ions adsorbed on Amberlite anion exchanger were available for the growth of maize plants. The use of potassium Amberlites inhibited the availability of Ca and Mg.

Arnon and Meagher (2) concluded that bentonite and Amberlite systems are similar throughout the entire range of complementary ion concentration so far as the exchangeability of potassium and calcium is concerned. Hydrogen resin was leached with potassium and calcium hydroxides.

Welch, et al. (23) demonstrated that adsorbed ions were excellent source of nutrients for growing plants. Yields were limited in the second and third crops by both nitrogen and cation levels. Potassium proved to be the limiting cation. Increases in nitrogen tended to increase potassium and magnesium contents in the lemon cuttings and in oats when the supply of cations was high. When the cation level was low for oats, and at all levels for radishes, increases in nitrogen had a tendency to decrease potassium. The latter effect was partly related to potassium depletion at the low cation levels combined with yield increases due to nitrogen.

Nishita, et al. (16) observed progressive increases in K and Na concentrations in barley tops and Sr 90, Ca, and Mg concentrations decreased with increasing addition of organic matter to the soil. Organic matter, directly or indirectly, appeared to have influenced mineral uptake by plants in several ways: microbial immobilization of ions, ionic antagonism, and "carbohydrate dilution" caused by increased plant yields. Although there was no direct evidence, certain decomposition products of organic matter might also influence mineral uptake by plants.

Nishita, et al. (17) further concluded that uptake of Na and K increased as organic matter concentration in the soil increased.

Street (21) found that aqueous extracts of the organic supplements used had no significant effect on oats.

The specific objectives of this study were: (1) to determine the effect of increasing the cation exchange capacity of the growth medium upon potassium availability; (2) to determine the effect of such increase in exchange capacity upon potassium availability as it exists in both continuously moistened and previously dried soil.

METHODS OF STUDY

Soil Material Used

Parsons silt loam surface soil was obtained from the Thayer Experiment Field in November, 1956. This southeastern Kansas soil material was used because of its comparatively low content of exchangeable potassium.

Laboratory Analyses

Laboratory analyses of Parsons silt loam were made with respect to pH,

lime requirement, available phosphorous, percent organic matter, and exchangeable potassium. Plant material was analyzed for uptake of potassium. The results of the initial laboratory analyses are shown in Table 1.

Table 1. Chemical properties of soil material used in greenhouse experiment.

pH	Lime requirement lbs./A	Available phosphorous lbs./A	Organic Matter content percent	Exchangeable potassium lbs./A
5.7	3000	8.8	1.1	164* 178** 195***

*fresh moist soil

**air dried for six months

***air dried for one month

The pH determination was made with the standard glass electrode using a soil to water ratio of 1:1. Lime requirement was established by combining use of a glass electrode and use of a buffered solution at pH 7 as suggested by Woodruff (25).

The colorimetric method of Bray and Kurtz (6) was used to determine available phosphorous. Available phosphorous was extracted from the soil with a solution that was 0.025 N with respect to HCl and 0.03 N with respect to NH_4F . A soil to solution ratio of 1:50 was used in the extraction of available phosphorous.

The procedure of Graham (8) was used for the determination of percent organic matter.

For the determination of exchangeable potassium in the soil, 10 grams of soil which passed a 10-mesh sieve were used. To this soil were added 50 mls. of 1 N ammonium acetate extracting solution. The mixture was then

shaken mechanically for 10 minutes. The suspension was filtered. A measured amount of solution containing an internal standard, lithium nitrate, was added to an aliquot of the filtrate. This was then analyzed for content of potassium by use of the Perkin-Elmer flame photometer.

Potassium in the plant material was determined by the method suggested by Attoe (4).

Preliminary Laboratory Study

Dried and continuously moistened samples of Parsons silt loam surface soil were used. The dried material had been exposed to drying conditions of the laboratory for a period of about three months. The continuously moistened sample contained 16 per cent of water at the time this study was initiated.

Sodium saturated resin and ground peat were added independently to samples of soil as indicated in Table 2. Five g. each of resin and peat were employed. The amount of soil corresponded to 100 g. of dry material. An untreated portion of each sample was included in the experiment as a control.

Following the mixing of soil material and the resin, 150 ml. of distilled water were added to each sample. The mixtures next were shaken for one hour by means of a mechanical shaker. This shaking procedure was repeated daily until seven cycles had been completed. At the end of the 7-day period the soil samples were separated from the liquid by means of filtration.

Following filtration, exchangeable potassium content of the soil was determined by the ammonium acetate-centrifuge method. The Beckman flame photometer was used to measure potassium in the extract. Determinations

of exchangeable potassium were made on both moist and oven-dried samples of each treatment.

Two g. of dried and three g. of moist soil were extracted by centrifuging the soil suspended in 50 ml. of 1 N ammonium acetate. This was done four times. The supernatant liquid was collected in a 250 ml. volumetric flask and brought to volume with the acetate solution.

The results of the preliminary laboratory study are given in Table 2.

Table 2. Results of the preliminary laboratory study involving sodium saturated resin.

Treatment	Exchangeable K, lbs./A		Soluble K in filtrate, lbs./A
	Moist soil	Oven-dried soil	
1. Air dry soil + 5 g. resin	192	165	4*
2. Air dry soil + 5 g. peat	149	155	0
3. Air dry soil alone	134	170	0
4. Moist soil + 5 g. resin	182	200	4*
5. Moist soil + 5 g. peat	133	145	0
6. Moist soil alone	162	190	0
7. Fresh moist soil	164	-	-
8. Air dry soil	-	156	-

*Sodium interfered with accurate measurement of K by use of flame photometer

This preliminary study was repeated by using hydrogen saturated resin. This experiment involved essentially the same details as the first except that where resin was used, only three g. were employed. In this trial, exchangeable potassium was determined by adding 50 ml. of 1 N ammonium acetate extracting solution to 10 g. of soil. This mixture was shaken mechanically for 10 minutes before it was filtered.

An internal standard, lithium nitrate, was added to a portion of the

filtrate. The filtrate was then analyzed for its content of potassium by means of the Perkin-Elmer flame photometer.

The results of this trial are presented in Table 3. Results of the two preliminary trials were used as a basis for the establishment of a greenhouse experiment.

Table 3. Results of a preliminary laboratory study involving hydrogen saturated resin.

Treatment	: Exchangeable K, lbs./A		: Soluble K in filtrate, lbs./A
	: Moist soil	: Oven-dried soil	
1. Air dry soil + 3 g. resin	158	304	71
2. Air dry soil + 5 g. peat	116	156	27
3. Air dry soil alone	144	178	27
4. Moist soil + 3 g. resin	168	272	62
5. Moist soil + 5 g. peat	116	228	27
6. Moist soil alone	136	256	31

Greenhouse Technique

Parsons silt loam surface soil was divided into two lots. One lot was maintained in a continuously moist state from November 23, 1956, until the time of planting (January 5, 1957). The moisture content did not go below 12 percent. One lot was dried in a forced air furnace until the moisture content was approximately 1.2 percent. After attainment of these moisture levels, 48 greenhouse containers were filled with soil from each of the two lots (one moist and one dry). The individual greenhouse containers received either 2500 grams of dried soil or 2828 grams of moist soil.

Each container of soil, irrespective of other treatments, received one gram of chemical grade diammonium phosphate fertilizer=(21.5-53-0).

Four levels of potassium were used on each lot of soil. Muriate of potash was applied to three of these at the rates indicated in Table 4.

Table 4. Amount of potassium added for various soil treatments.

Potash treatment, rate of K_2O (lbs./A)	:	Amount of KCl added g./pot
0	:	-
80	:	0.159
160	:	0.318
320	:	0.636

Amberlite IR-120 (H), a nuclear sulfonic-acid type resin, was applied to 16 pots of each of the moist and dry soil at a rate of 90 g. of dry resin per pot. The exchange capacity of the Amberlite resin was 5 me./dry gram. This was a sufficient amount of resin to double the exchange capacity of the growth media in a given pot.

Organic matter in the form of ground peat was added to 16 pots of each of the moist and dry soil at a rate of 250 g. per pot. This amount also was approximately sufficient to double the exchange capacity of the growth media in a given pot.

The soybeans were planted on January 5, 1957. Poor germination was observed. Soil samples were taken from the control, resin, and peat cultures, both moist and previously dried soils. The pH value of each was determined and the results are given in Table 5.

Table 5. The pH of treated soils and amount of calcium hydroxide added to correct soil acidity.

Treatment	pH	Ca (OH) ₂ added, g./pot
No treatment	6.4	---
Ground peat	4.6	8.2
Amberlite	2.7	16.4

The calcium hydroxide was thoroughly mixed with the respective pots. Soybeans were replanted on January 19, 1957.

Two successive crops of soybeans were planted and harvested at about the time of bean formation. The third crop was harvested at about the time of blossom formation. Plant material was dried and weighed to permit determination of yields of plant material. It also was analyzed for content of potassium.

EXPERIMENTAL RESULTS

Preliminary Laboratory Studies

In the preliminary laboratory studies reported in Table 2 a portion of soil was used which was collected from the Thayer Experiment Field in the early spring of 1955. This sample had been stored in a sealed quart fruit jar in the laboratory until the fall of 1956 when it was opened and used for this particular study. It was collected at a spot relatively close to the one chosen for the collection of the soil in the fall of 1956. The studies reported in Table 3 were performed upon a sample of soil collected at the latter time. During the 1955 season the soil involved in the latter study had produced a crop of corn and in 1956 it had produced a crop of soybeans. This subsequent production of two crops and the variation in times of

collection (spring vs. fall collection) as well as the effect of two years storage under warm moist laboratory conditions may have caused some variation in the behaviors of these two samples. It was felt, however, that the use of these two samples in the preliminary laboratory trials yielded information which was useful both in the establishment of the greenhouse investigation and in explaining results which were obtained throughout the course of the investigation.

Where previously air-dried soil was used, and at the end of the seven-day period, there were only 134 pounds per acre of exchangeable potassium present in the moist soil. This was 28 pounds per acre less than was present in the soil which had been kept continuously moistened prior to this laboratory study. For some reason during the seven days exposure to the laboratory trial this sample (the one initially air-dried) seemed to fix some potassium into nonexchangeable forms.

Addition of peat to the previously air-dried soil seemed to eliminate a small amount of potassium fixation. At least where such addition was made the soil contained 149 pounds per acre of exchangeable K as compared to only 134 pounds per acre where nothing was added. The addition of Amberlite resin was even more effective in this regard. Soil treated in this manner contained 192 pounds per acre of exchangeable potassium. This was substantially above that contained in either of the other two samples discussed for the previously air-dried series.

With continuously moistened soil the same general trend held where Amberlite resin was involved. Addition of this substance resulted in the presence of an extra 20 pounds per acre of exchangeable potassium at the end of the seven day laboratory experiment. Peat addition under these same conditions did not exert any beneficial effect of this sort. As a matter of

fact it appeared that a substantial amount of potassium was fixed into nonexchangeable forms as a result of this particular treatment.

The effects of subsequent oven-drying were not especially marked in any instance. However, there usually was a small increase in the amount of exchangeable potassium after this particular treatment. The amount released varied from six to 36 pounds per acre. Where Amberlite resin was involved with the previously air-dried soil, the subsequent oven-drying did not release potassium; rather there was a loss of 27 pounds per acre of exchangeable potassium.

Apparently treatment of soil with Na^+ -resin was just as effective as treatment with H^+ -resin insofar as the influence of the resin alone was concerned. However, the influence of H^+ resin was much more significant insofar as the subsequent combined effects of this treatment and oven-drying were concerned. Apparently treatment with Na^+ resin followed by oven-drying was much less effective, particularly where the air-dried soil was involved.

Only a small amount of water soluble potassium was released into the filtrate and that release was confined to the resin treated samples. The release effected as a result of use of Na^+ resin (Table 2) was much less than that noted for use of H^+ resin (Table 3). Presence of sodium in the filtrate seriously interfered with the measurement of the small amount of potassium which was present so these results may not be entirely valid.

Where air-dried soil was used, and at the end of the seven-day period, there were 144 pounds of exchangeable potassium present in the moist soil. This amount was only eight pounds more than in the soil which had been kept continuously moistened. No doubt during the seven days exposure to the laboratory trial the two samples had more or less achieved somewhat similar equilibria.

Where peat was added, each had 116 pounds per acre of exchangeable potassium at the end of seven days. There certainly was no evidence that peat had effected a release of potassium to the exchangeable form. However, where the Amberlite resin saturated with H^+ was supplied, it brought about an increase in exchangeable potassium. This amounted to only 14 pounds per acre in the case of the air-dried series but it amounted to 32 pounds in the case of the moist soil series.

After the soil samples had been oven-dried there was a big increase in the amount of exchangeable potassium in the soils. This effect was especially pronounced on the soil series which had always been kept moistened. In each of the three samples, this drying operation consistently effected the release of more than 100 pounds per acre of exchangeable potassium. It also was interesting to note that the previous effects of adding peat and resin still held. The sample treated by adding peat still had the least content of exchangeable potassium and that treated by adding the resin still had the most. It appeared that the effects of H^+ -resin addition and peat addition were quite independent of those induced by subsequent drying.

The soil which was air-dried before conducting this preliminary experiment did not show such a large gain in exchangeable potassium as a result of subsequent oven-drying except in the case where H^+ -resin was added during the intervening laboratory trials. Where either soil alone was involved or where soil plus peat was used, this particular drying cycle effected the release of from 34 to 40 pounds per acre of exchangeable potassium. However, with that soil which had H^+ -resin added, the release amounted to 146 pounds per acre of exchangeable potassium.

In the trials reported in Table 3, there was some release of potassium as a water soluble constituent. The amount was rather small (ranging from

27 to 31 pounds per acre) wherever soil alone or soil plus peat was involved. It was quite substantial (62 pounds per acre on the continuously moist series and 71 pounds per acre on the previously air-dried series) wherever soil plus resin was involved. It was obvious that H^+ -resin effected the release of considerable potassium into water soluble forms.

Measurements of exchangeable soil potassium made throughout the course of the two preliminary trials consistently indicated low values. It was suggested in the preliminary trials that addition of H^+ -resin could be expected to effect a release of potassium to available forms. This suggestion held both insofar as increases in exchangeable potassium were concerned and also insofar as increases in water-soluble potassium were concerned.

It was felt that the use of a greenhouse experiment to measure the behavior of soil potassium in the presence of actively growing plant roots would shed additional information along these lines. The results presented in the succeeding paragraphs were so obtained.

Yield Results

Yields of soybean plant material are presented in Tables 6, 7, 8 and 9.

Yield data for the first crop of soybeans are given in Table 6. Where potash was not added, the yields were 7.6 and 7.3 g. per pot respectively for the dried and the continuously moist series. These yields were among the very largest obtained. Analysis of variance indicated that a least significant difference of 1.3 g. per pot was required at the 5 percent level. Therefore, the yield of any culture on the dried series which amounted to less than 6.3 g. per pot yielded significantly less than the corresponding control. Similarly any yield of a culture on the moist series which amounted

Table 6. Relationship between potassium applied and yield of first crop of soybean plant material under various greenhouse conditions.

K ₂ O Applied (lbs./A)	Yield of soybean plants (g./pot)					
	Control		Amberlite Resin		Ground peat	
	Dried	Moist	Dried	Moist	Dried	Moist
0	7.6	7.3	5.8	6.0	5.0	5.0
80	6.7	6.7	5.5	5.7	5.4	5.9
160	7.6	6.4	5.9	5.7	6.2	6.9
320	7.2	6.4	5.4	5.4	4.7	6.0
Average for Moisture Conditions	7.3	6.7	5.7	5.7	5.3	6.7
Average for Culture Media	7.0		5.7		6.0	

Least significant difference between individual culture values (.05) = 1.3g./pot

Table 7. Relationship between potassium applied and yield of second crop of soybean plant material under various greenhouse conditions.

K ₂ O Applied (lbs./A)	Yield of soybean plants (g./pot)					
	Control		Amberlite Resin		Ground Peat	
	Dried	Moist	Dried	Moist	Dried	Moist
0	36.7	30.4	28.6	35.7	32.1	31.4
80	36.7	31.0	32.4	31.1	31.3	35.1
160	32.6	33.1	32.0	32.4	37.8	33.1
320	35.5	31.1	33.8	34.9	34.0	32.2
Average for Moisture Conditions	34.8	31.2	31.7	33.5	33.8	33.0
Average for Culture Media	33.1		32.6		33.4	

Difference in yields are non-significant.

Table 8. Relationship between potassium applied and yield of third crop of soybean plant material under various greenhouse conditions.

K ₂ O Applied (lbs./A)	Yield of soybean plants (g./pot)					
	Control		Amberlite Resin		Ground Peat	
	Dried	Moist	Dried	Moist	Dried	Moist
0	6.4	6.3	6.9	7.7	8.1	7.9
80	6.3	6.8	6.9	6.7	8.3	7.9
160	6.0	6.8	7.1	7.3	8.8	9.5
320	7.1	7.2	7.5	8.5	8.3	7.8
Average for Moisture Conditions	6.4	6.8	7.1	7.6	8.4	8.3
Average for Culture Media	6.6		7.3		8.4	

Least significant difference between individual culture values (.05) = 1.7g./pot (.01) = 2.3g./pot

Table 9. Relationship between potassium applied and yield of three combined crops of soybean plant material under various greenhouse conditions.

K ₂ O Applied (lbs./A)	Yield of soybean plants (g./pot)					
	Control		Amberlite Resin		Ground Peat	
	Dried	Moist	Dried	Moist	Dried	Moist
0	50.7	44.0	41.3	49.4	46.1	47.3
80	49.7	44.5	44.8	43.5	44.9	48.9
160	46.2	46.3	48.0	45.4	52.8	49.5
320	47.6	44.7	46.9	49.8	47.0	46.0
Average for Moisture Conditions	48.6	44.9	44.5	46.8	47.7	47.9
Average for Culture Media	46.8		45.6		47.8	

Differences in individual total yields are non-significant.

to less than 6.0 g. per pot was significantly less than its corresponding control.

It was observed with the dried series that every culture to which H^+ saturated Amberlite resin had been added yielded significantly less than the corresponding control. This same relationship held insofar as peat cultures were concerned on the dried series except the one to which 160 pounds per acre of potash had been added.

Similarly with the wet series every culture to which Amberlite resin had been added yielded significantly less than its corresponding control. There were two exceptions, where 80 and 320 pounds per acre of K_2O had been added, in the case of the peat cultures on the wet series which did not yield significantly less than the moist control.

When the yield averages for the various levels of potash fertilization were considered, it was quite obvious that no general response had occurred. Similarly by comparing the yield averages for the various soil cultures, it was quite apparent that Amberlite and peat additions caused appreciable yield decreases with the first crop of soybeans. A like consideration of the averages of the various dried and moist series suggested no consistent pattern of behavior.

Variations in the individual culture yields of soybeans for the second crop were not statistically significant. There was no indication of yield response to potash fertilization. The variations in average yields of plant material among the three types of growth media (control, Amberlite resin, peat) were so small as to suggest no trend whatsoever. Likewise it did not appear that previous moisture status of the soil (dried vs. moist) had any bearing on yields obtained for this crop.

The third crop of soybeans produced certain variations in yields. Where

no potash was added, the control yield was 6.4 g. per pot on the dried series and 6.3 g. per pot on the moist series. Analysis of variance indicated significance at both the five and one per cent levels with the least significant difference at the five per cent level being 1.7 g. per pot. Therefore, any value on the dried series with yield greater than 8.1 ($6.4 + 1.7$) grams per pot yielded significantly more than the dried control. Consequently, every culture (0, 80, 160 & 320 lbs./A K_2O) on the dried series to which peat had been added yielded significantly more than the control of the dried series.

Similarly on the moist series, any value greater than 8.0 ($6.3 + 1.7$) grams per pot yielded significantly more than the moist control. Consequently, one culture (160 lbs./A K_2O) on the moist series to which peat had been added yielded significantly more than the control. Also, the other three cultures (0, 80 & 320 lbs./A K_2O) were essentially large enough to be significantly greater than the moist control. Only one other instance, namely where 320 lbs./A of K_2O had been applied to the moist soil to which Amberlite resin had been added, produced a significantly greater yield than the control. That yield was 8.5 grams per pot.

It was quite noticeable that addition of Amberlite resin and peat to the soil resulted in increased yields of the third crop of soybeans. An average of all pots receiving Amberlite resin yielded .7 grams per pot more than an average of all check pots. An average of all pots receiving peat yielded 1.8 grams per pot more than an average of all check pots.

There was no significant variations in average yields of the soybeans when the totals of the three crops were considered.

Effect of Amberlite Resin and Peat Upon Uptake of Potassium by Plants

Indicated in Fig. 1 are the results indicating potassium uptake by the first soybean crop produced on the dried soil series. The control pots consistently yielded more total potassium than did the pots to which either Amberlite or peat was added. The soil-peat mixture supplied more potassium to soybean plants than did the Amberlite-soil mixture at all levels of fertilization except where 320 pounds per acre of potash had been applied.

Figure 2 presents potassium uptake data for the first crop of soybeans which was harvested from the moist soil series. Again, the control pots supplied more potassium at all levels of fertilization than did the soil-Amberlite mixture. The control and peat cultures supplied essentially the same amounts of potassium. The moist soil series furnished higher levels of available potassium than did the dry soil series. There was no response in potassium uptake by plants to application of potash fertilizer.

Potassium uptake data for the second crop of soybeans produced on the dried soil series are reported in Fig. 3. The Amberlite-soil mixture furnished more available potassium than did the control cultures at all potash treatment levels. The peat-soil mixture supplied less potassium than any other cultures except where 160 and 320 pounds per acre of potash had been used. These cultures supplied approximately the same amounts of potassium as did the Amberlite-soil cultures.

In Fig. 4 are reflected the potassium uptake results for the second crop of soybeans grown on the moist soil series. The uptake of potassium on this series was considerably lower than was the uptake on the dried soil series except for a response from the 80 and 160 pounds per acre applications of potash. The peat-soil mixture supplied the greatest amounts of potassium

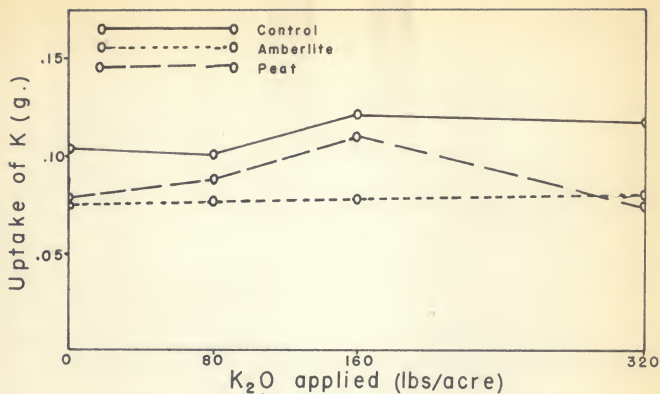


Fig. 1. Uptake of potassium by the first crop of soybeans grown on dried Parsons silt loam.

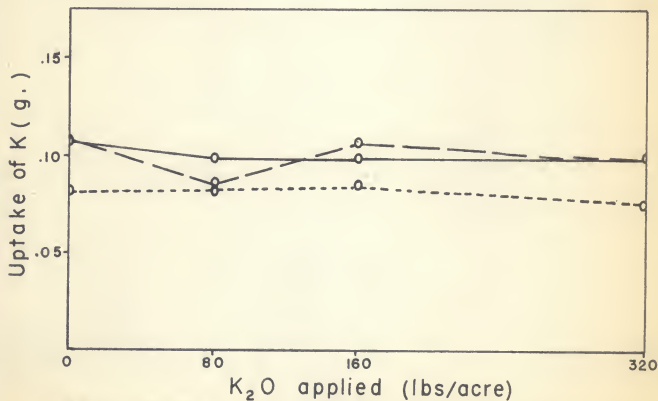


Fig. 2. Uptake of potassium by the first crop of soybeans grown on moist Parsons silt loam.

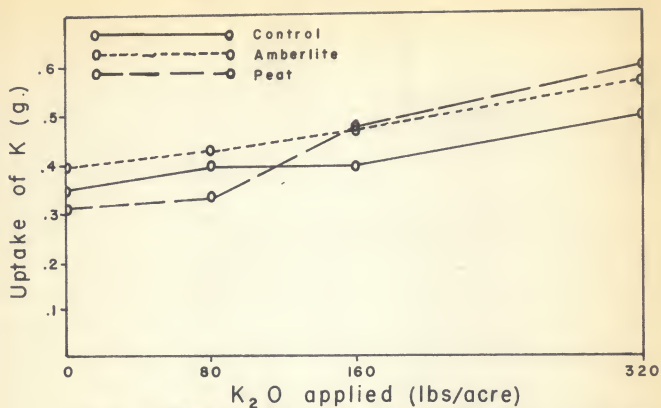


Fig. 3. Uptake of potassium by the second crop of soybeans grown on dried Parsons silt loam.

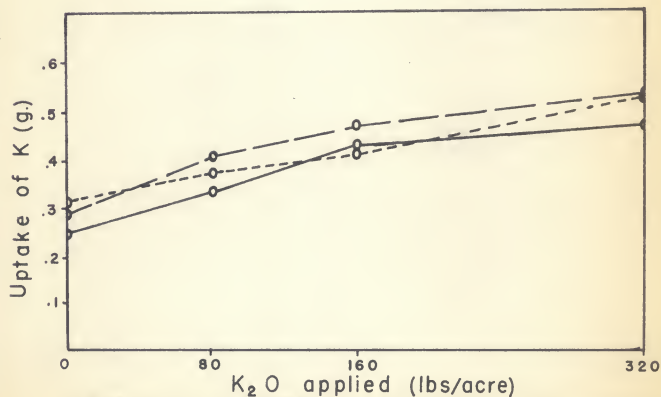


Fig. 4. Uptake of potassium by the second crop of soybeans grown on moist Parsons silt loam.

except where potash was not added and where 320 pounds per acre were used. In these cases the uptake of potassium was approximately equal to the amount supplied by the soil-resin mixture. The Amberlite-soil mixture generally maintained a higher level of potassium availability than did the control except where 160 pounds per acre of potash had been applied. These two were about equal in magnitude. The resin-soil mixture yielded slightly more potassium where potash was not added than did the peat-soil mixture. This relationship was reversed when potash fertilizer was applied. This indicated that moist soil with large amounts of organic matter incorporated into it does not fix as much added fertilizer potassium.

Indicated in Fig. 5 are the results reflecting potassium uptake by the third soybean crop produced on the dried soil series. The Amberlite-soil mixture consistently yielded more total potassium than did the control cultures or soil-peat mixture. The control culture supplied more potassium to soybean plants than did the soil-peat mixture except where potash was not applied and where 160 pounds per acre of potash were used.

Figure 6 presents potassium uptake data for the third crop of soybeans which was harvested from the moist soil series. The plot of the potassium uptake from the Amberlite-soil mixture is higher than and parallel to the plot of the potassium uptake from the control culture except where 320 pounds per acre of potash had been applied. The peat culture supplied less potassium to soybean plants than did the Amberlite and control cultures at all levels of fertilization except where 160 pounds per acre of potash had been used. The application of 320 pounds per acre of potash to the soil alone and to the Amberlite-soil mixture resulted in especially high uptake of potash by the third crop of soybean plants.

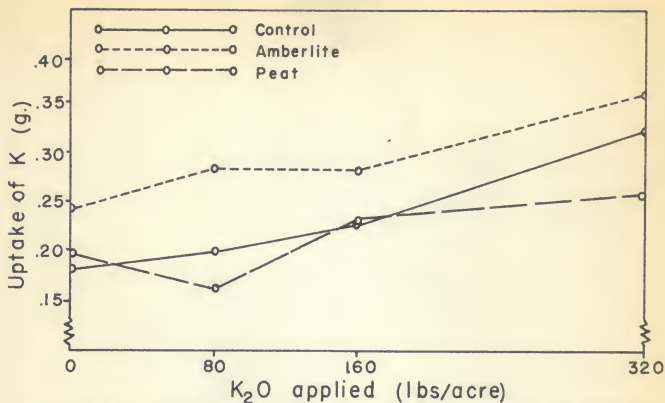


Fig. 5. Uptake of potassium by the third crop of soybeans grown on dried Parsons silt loam.

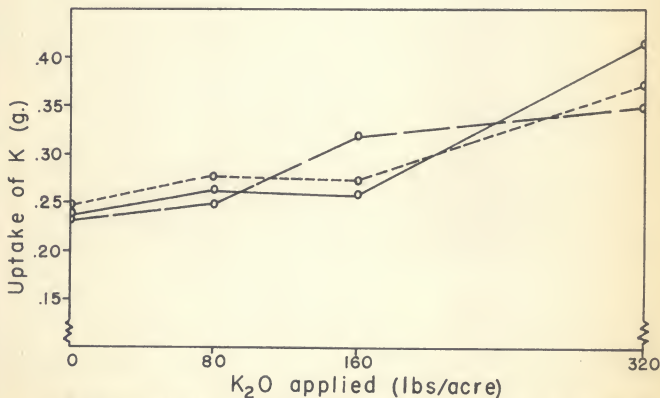


Fig. 6. Uptake of potassium by the third crop of soybeans grown on moist Parsons silt loam.

As may be seen in Fig. 7, more total potassium was accumulated by three crops of soybeans grown on the dried series of Amberlite-soil mixture than on either the dried soil alone or on the dried soil-peat mixture. There was no consistent pattern for the soil peat-mixture but on the average it apparently behaved about like the soil alone.

In the case of the moist soil series as shown in Fig. 8, the Amberlite-soil mixture was not effective insofar as increasing the uptake of potassium by soybean plants was concerned. Peat-soil mixture was somewhat effective in this regard, especially where 180 pounds per acre of potash were supplied.

It may be seen in Fig. 9 that soybeans generally accumulated similar amounts of potassium from dried soil and from moist soil, where no attempt was made to alter the cation exchange capacities.

Figure 10 presents data for the soybean crops grown on the Amberlite-soil mixture. The dried soil consistently supplied more potassium to plants than did the continuously moist soil. It also was interesting to note that the plot of the uptake was essentially a linear function of the amount of potash applied.

Results for the crops grown on the soil-peat mixtures are reported in Fig. 11. Drying had relatively small effect upon potassium availability where potash fertilizer was not applied and where 320 pounds per acre were furnished. Drying decreased uptake considerably with the addition of 80 pounds per acre of potash.

SUMMARY AND CONCLUSIONS

In answer to the original objectives of this study it was found that:

- (1) Increasing the cation exchange capacity by mixing small amounts of both H^+ - saturated and Na^+ - saturated Amberlite resins with Parsons silt loam

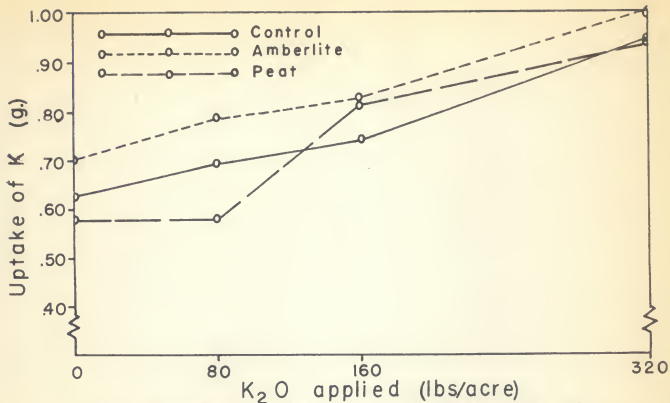


Fig. 7. Uptake of potassium by the three crops of soybeans grown on dried Parsons silt loam.

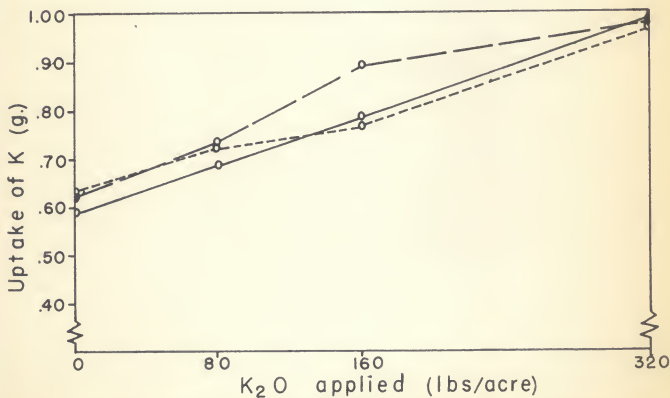


Fig. 8. Uptake of potassium by the three crops of soybeans grown on moist Parsons silt loam.

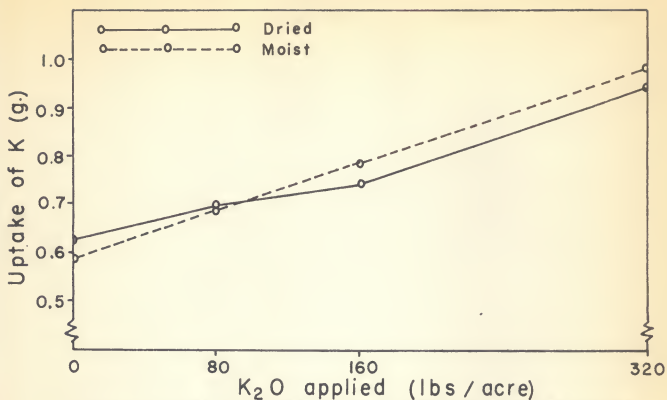


Fig. 9. Uptake of potassium by three crops of soybeans grown on the Parsons silt loam control culture.

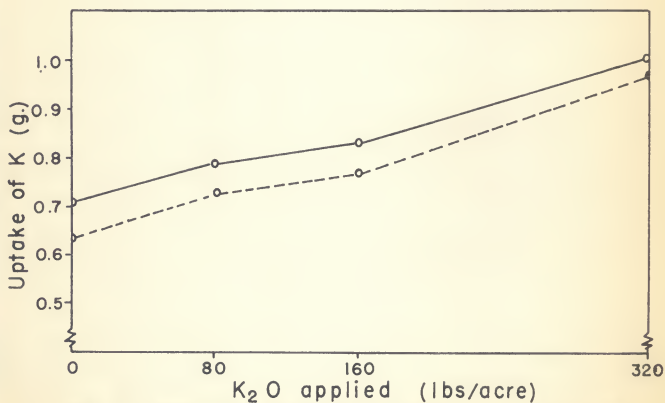


Fig. 10. Uptake of potassium by three crops of soybeans grown on the Parsons silt loam-Amberlite culture.

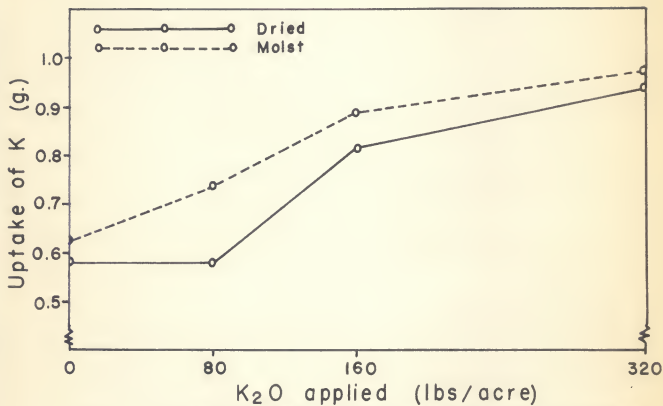


Fig. II. Uptake of potassium by three crops of soybeans grown on the Parsons silt loam-peat culture.

increased the amount of exchangeable potassium. The effect of this treatment was especially evident where H^+ -resin was employed. In this case the effect was especially pronounced after the soil had been oven-dried. Addition of H^+ -saturated resin had a definite tendency to increase the amount of water soluble potassium in the soil.

The above effects did not apply to the first two crops of soybeans grown in the greenhouse. Growth of the first crop was poor wherever either resin or peat was incorporated with the soil. The second crop produced rather uniform growth on all types of culture media. With the third crop, it appeared that some beneficial effects could be attributed to additions of either resin or peat.

(2) Drying of the soil prior to the actual accomplishment of the experimental laboratory trials had only a limited effect upon the exchangeable potassium content. This undoubtedly was due to the fact that rather similar equilibria were established during the time that various lots of soil were allowed to stand in aqueous suspension. However, subsequent oven-drying had a profound tendency to increase the exchangeable potassium content. This increase was especially significant where H^+ -saturated resin had been incorporated with and allowed to remain in contact with the soil during the seven days that the soil was allowed to stand in aqueous suspension in the laboratory.

Again the above effects as observed in the laboratory did not seem to apply to the first crop of soybeans grown in the greenhouse. The beneficial effects of Amberlite resin first were observed with the second crop insofar as potassium uptake was concerned. Somewhat the same effect was true for peat at the time the second crop was produced. These effects became even more pronounced at the time the third crop was produced.

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The author wishes to express his sincere appreciation to his major instructor, Dr. F. W. Smith, for his interest and helpful advice in conducting this research problem and the preparation of this thesis.

LITERATURE CITED

- (1) Arnon, D. I., and K. A. Grossenbacher.
Nutrient culture of crops with the use of synthetic ion-exchange materials. *Soil Sci.* 63:159-180. 1947.
- (2) Arnon, D. I., and W. R. Meagher.
Factors influencing availability of plant nutrients from synthetic ion-exchange materials. *Soil Sci.* 64:213-221. 1947.
- (3) Attoe, O. J.
Potassium fixation and release in soils occurring under moist and drying conditions. *Soil Sci. Soc. Amer. Proc.* 11:145-149. 1946.
- (4) Attoe, O. J.
Rapid photometric determination of potassium and sodium in plant tissue. *Soil Sci. Soc. Amer. Proc.* 12:131-134. 1947.
- (5) Bower, C. A., and C. H. Wadleigh.
Growth and cationic accumulation by four species of plants as influenced by various levels of exchangeable sodium. *Soil Sci. Soc. Amer. Proc.* 13:218-223. 1948.
- (6) Bray, R. H., and T. Kurtz.
Determination of total, organic and available forms of phosphorous in soils. *Soil Sci.* 59:39-45. 1945.
- (7) Fine, L. O., T. A. Bailey, and E. Truog.
Availability of fixed potassium as influenced by freezing and thawing. *Soil Sci. Soc. Amer. Proc.* 5:183-186. 1941.
- (8) Graham, E. R.
Determination of soil organic matter by means of a photoelectric colorimeter. *Soil Sci.* 65:181-183. 1948.
- (9) Graham, E. R., and W. A. Albrecht.
Nitrate absorption by plants as an anion exchange phenomenon. *Amer. Jour. Bot.* 30:195-198. 1943.
- (10) Hoagland, D. R., and J. C. Martin.
Absorption of potassium by plants in relation to replaceable, and soil solution potassium. *Soil Sci.* 36:1-33. 1933.
- (11) Lambeth, V. W.
Cationic saturation of low exchange soils for growth of vegetable crops. *Missouri Agricultural Experiment Research Bulletin* 575: 1-35. 1955.
- (12) Legg, J. Ol, and R. L. Beachler.
The potassium supplying power of representative Arkansas soils. *Soil Sci. Soc. Amer. Proc.* 16:210-214. 1952.

- (13) Liebig, G. F., A. P. Vanselow, and H. D. Chapman.
The suitability of water purified by synthetic ion-exchange resins for the growing of plants in controlled nutrient cultures. *Soil Sci.* 55:370-376. 1943.
- (14) Luebs, R. E., G. Stanford, and A. D. Scott.
Relation of available potassium to soil moisture. *Soil Sci. Soc. Amer. Proc.* 20:45-50. 1956.
- (15) Nielsen, T. R., and R. Overstreet.
Study of the role of the hydrogen ion in the mechanism of potassium absorption by excised barley roots. *Plant Physiology.* 30:303-309. 1955.
- (16) Nishita, H., B. W. Kowalewsky, and K. H. Larson.
Influence of soil organic matter on mineral uptake by barley seedlings. 82:307-318. 1956.
- (17) Nishita, H., B. W. Kowalewsky, and K. H. Larson.
Influence of soil organic matter on mineral uptake by tomato plants. *Soil Sci.* 82:401-407. 1956.
- (18) Pratt, P. F., R. H. Simon, and G. W. Volk.
Release of potassium from nonexchangeable forms in relation to soil reaction. *Soil Sci. Soc. Amer. Proc.* 20:190-192. 1956.
- (19) Reitemeier, R. F.
Soil potassium. *Advances in Agronomy Vol. III.* pp. 113-159. Academic Press Inc., New York. 1951.
- (20) Scott, T. W. and F. W. Smith.
Effect of drying upon availability of potassium in Parsons silt loam surface soil and subsoil. *Agron. Jour.* 49:(in print). 1957.
- (21) Street, H. E.
Studies in plant nutrition - effect of some organic supplements on growth of plants in sand culture. *Annals of Applied Biology.* 37: 149-158. 1950.
- (22) Volk, W. J.
The fixation of potash in difficultly available forms in soils. *Soil Sci.* 37:267-287. 1934.
- (23) Welch, H. V., Jr., A. Wallace, and R. T. Mueller.
Influence of factorially combined levels of cations and nitrate ions absorbed on ion-exchange resins on the nutrient absorption by plants. *Soil Sci. Soc. Amer. Proc.* 18:137-140. 1954.
- (24) Williams, D. E., and H. Jenny.
The replacement of nonexchangeable potassium by various acids and salts. *Soil Sci. Soc. Amer. Proc.* 16:216-221. 1952.

(25) Woodruff, C. M.

Testing soils for lime requirement by means of a buffered solution and the glass electrode. Soil Sci. 66:53-63. 1948.

POTASSIUM AVAILABILITY IN PARSONS SILT
LOAM AS INFLUENCED BY SOIL DRYING AND
ALTERATION OF THE CATION EXCHANGE CAPACITY

by

DONALD LEROY REED

B. S., Kansas State College
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AN ABSTRACT OF A THESIS

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This investigation was designed to study the effect of increasing the exchange capacity of both continuously moistened and previously dried soil upon potassium availability. For this purpose, Parsons silt loam surface soil was obtained from the Thayer Experiment Field.

A sample of soil previously obtained from the Thayer Experiment Field was divided in two lots, dried and continuously moistened. Sodium saturated resin and ground peat were added independently to samples of the soil. An untreated portion of each sample was included as a control. After addition of distilled water, the samples were shaken one hour per day for seven days. After filtering, exchangeable potassium content of the soil was determined by the ammonium acetate-centrifuge method. The Beckman flame photometer was used to measure potassium in the extract.

The laboratory study was repeated using hydrogen saturated resin. Results of the two preliminary trials were used as a basis for the establishment of a greenhouse experiment.

Parsons silt loam surface soil was divided into two lots. One lot was maintained in a continuously moist state. The moisture content did not go below 12 percent. One lot was dried in a forced air furnace until the moisture content was approximately 1.2 percent. After attainment of these specified moisture levels, 48 greenhouse containers were filled with soil from each of the two lots.

Each greenhouse container of soil irrespective of other treatments received one gram of chemical grade diammonium phosphate fertilizer (21.5-53-0).

Four levels of potassium were used on each lot of soil.

Amberlite LR-120 (H) was applied to 16 pots of each of the moist and dry soil at a rate of 90 g. of dry resin per pot. This was a sufficient amount of resin to double the exchange capacity of the growth media in a given pot.

Organic matter in the form of ground peat was added to 16 pots of each of the moist and dry soil at a rate of 250 g. per pot. This amount also was approximately sufficient to double the exchange capacity of the growth media in a given pot.

The soybeans were planted on January 5, 1957. Poor germination was observed. Soil samples were taken and pH determined. Calcium hydroxide was thoroughly mixed with the cultures containing Amberlite and ground peat to return the pH to the level of the control culture.

Two successive crops of soybeans were planted and harvested at about the time of pod formation. The third crop was harvested at about the time of blossom formation. Yields of plant material and potassium uptake were determined.

Increasing the cation exchange capacity by mixing small amounts of both sodium saturated and hydrogen saturated Amberlite resins with Parsons silt loam increased the amount of exchangeable potassium. The effect of this treatment was especially evident where hydrogen saturated resin was employed. In this case the effect was especially pronounced after the soil had been oven dried. The addition of hydrogen saturated resin had a definite tendency to increase the amount of water soluble potassium in the soil.

Growth of the first crop was poor wherever either resin or peat was incorporated with the soil. The second crop produced rather uniform growth on all types of culture media. With the third crop, it appeared that some beneficial effects upon yield could be attributed to addition of either resin or peat.

Drying of the soil prior to the actual accomplishment of the experimental trials had only a limited effect upon the exchangeable potassium content. This was undoubtedly due to the fact that rather similar equilibria were

established during the period that the soils were standing in aqueous suspension. Subsequent even-drying had a profound tendency to increase the exchangeable potassium content. This tendency was especially significant where hydrogen saturated Amberlite was incorporated into the soil.

Again, the effects observed in the laboratory did not seem to apply to the first crop of soybeans grown in the greenhouse. The beneficial effects of Amberlite resin first were observed with the second crop insofar as potassium uptake was concerned. Somewhat the same effect was true for peat. These effects became even more pronounced at the time the third crop was produced.